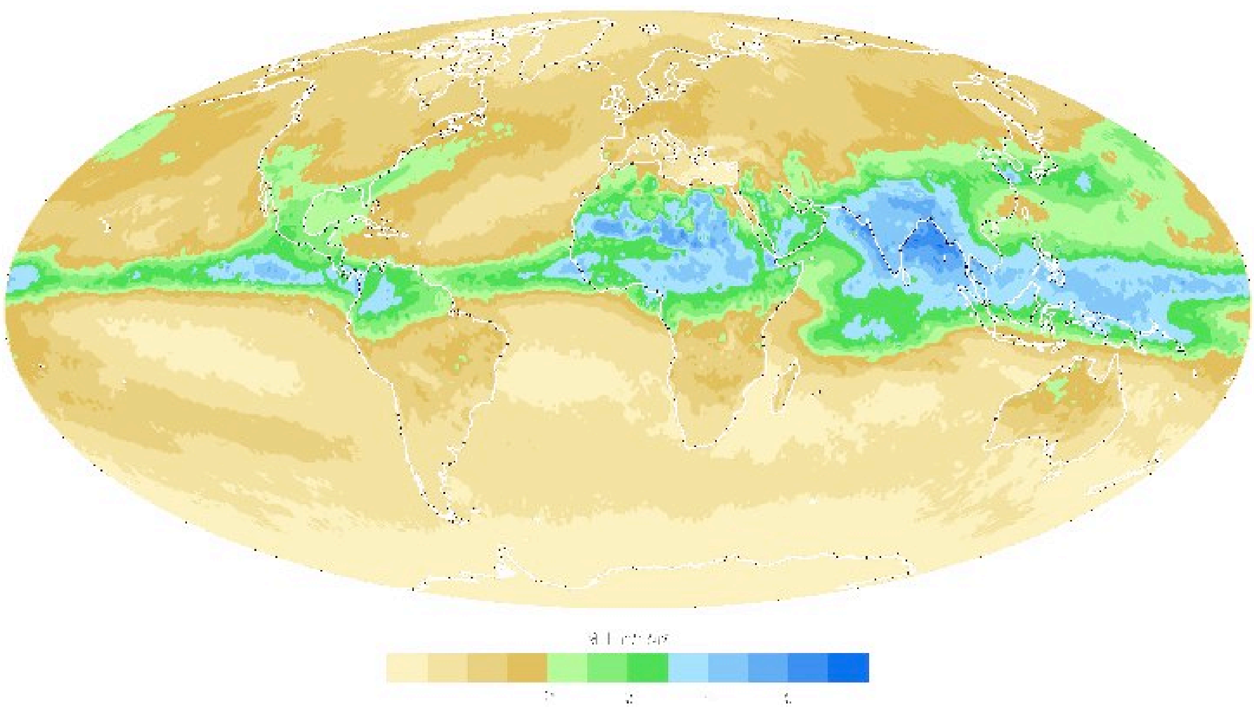
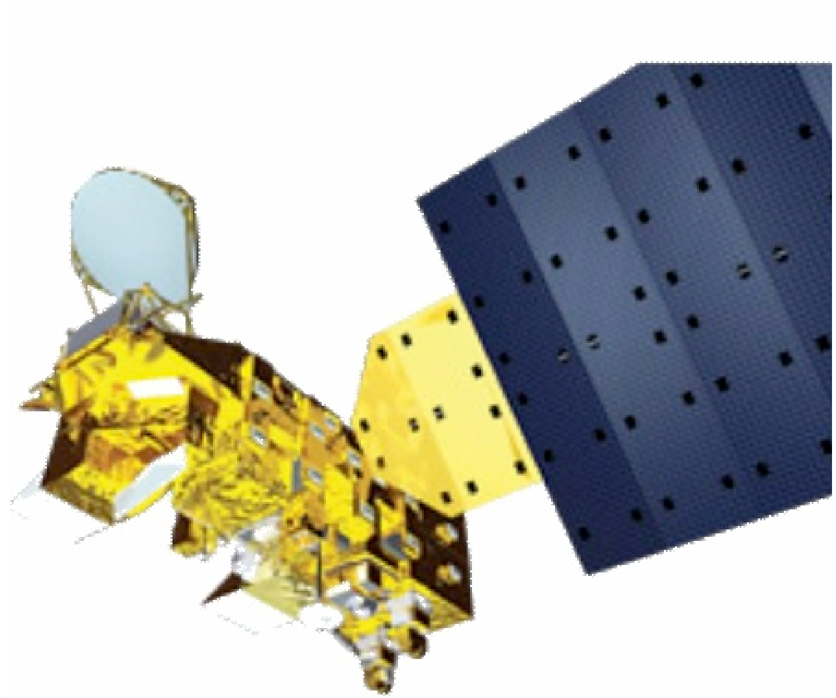
AIRS Atmospheric Infrared Sounder Status

George H. Aumann
Project Scientist
30 Nov 2004



AIRS/AMSU/HSB Project Overview

Spacecraft:	**EOS Aqua**
Instruments:	**AIRS, AMSU, HSB, MODIS, CERES, AMSR-E**
Launch Date:	**May 4, 2002**
Launch Vehicle:	**Boeing Delta II Intermediate ELV**
Mission Life:	**5 years**
Team Leader:	**Moustafa Chahine**

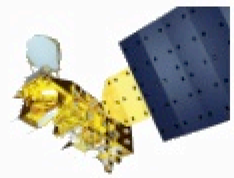


<u>AIRS Project Objectives</u>

1. **Support Weather Forecasting**
2. **Climate Research**
3. **Atmospheric Composition and Processes**

AIRS Data Distribution for Weather and Science

AIRS Data Distributed World Wide
For Weather Forecasting



NOAA
NESDIS
(Weather)

GSFC
DAAC
(Science)

DIRECT
BROADCAST
(Weather)

NWP Centers
NCEP, GLA, CMC, JMA, FNMOC,BOM, UK Met, ECMWF, Meteo Fr., DWD

- **Science Community**
- **Public**

- **Universities**
- **Local Weather Stations**
- **Brazil (INPE)**
- **China**
- **Korea**
- **DoD**
- **Other International**

AIRS/AMSU/HSB Standard Products

Radiance Products (Level 1B)	RMS Requirement	Current Estimate
AIRS IR Radiance	3%*	<0.2K
AIRS VIS/NIR Radiance	20%	10-15%
AMSU Radiance	0.25-1.2 K	1-2 K
HSB Radiance	1.0-1.2 K	N/A
Standard Core Products (Level 2)		
Cloud Cleared IR Radiance	1.0 K	<1.0 K
Sea Surface Temperature	0.5 K	1.0 K
Land Surface Temperature	1.0 K	TBD
Temperature Profile	1 K	1K
Humidity Profile	15%	15%
Total Precipitable Water	5%	5%
Fractional Cloud Cover	5%	TBD
Cloud Top Height	0.5 km	TBD
Cloud Top Temperature	1.0 K	TBD

*Absolute Relative to NIST

AIRS/AMSU/HSB Instrument Status

Quality Assurance Flags

Level 1b Status

Level 2 Status

- Radiative Transfer
- Cloud Clearing
- Retrievals

Data Assimilation

Research Data Products

Plans

AIRS/AMSU-A Instrument Status

- AIRS
  - Excellent health
  - No trends in almost all currents, temperatures, and voltages
    - Cooler active drive levels creeping up very slowly—at present rate of increase we should never have to de-ice
    - Chopper drive current, chopper drive delay, chopper phase slowly increasing
      - The levels are far below alarm levels, but potential effect on M11 and M12 channel are being monitored
    - Both of the above trends are thought to be due to slow ice build up
    - Since launch, 20 channels have experienced increased noise (all but one due to radiation dosage effects)—14 of these have recovered after temperature cycling, leaving just six detectors which were good at launch but not today
- AMSU-A
  - Age is starting to show
  - Change in electronics since launch are gain degradations of about 17% in Channel 5 and about 5% in Channel 6 (accounted for in the two point calibration)
  - Temperature sensors became noisy in Nov 04

Quality Assurance (QA) Flags are used to alert the user of out-of-spec conditions

The L1b files include all spectral radiances measured by AIRS

They have been radiometrically calibrated.
The data have not been tuned, edited, apodized, shifted or re-registered
QA flags are set as necessary

The L2 files include results from all all processed spectra.
If the solution does not converge at key points appropriate flags is set

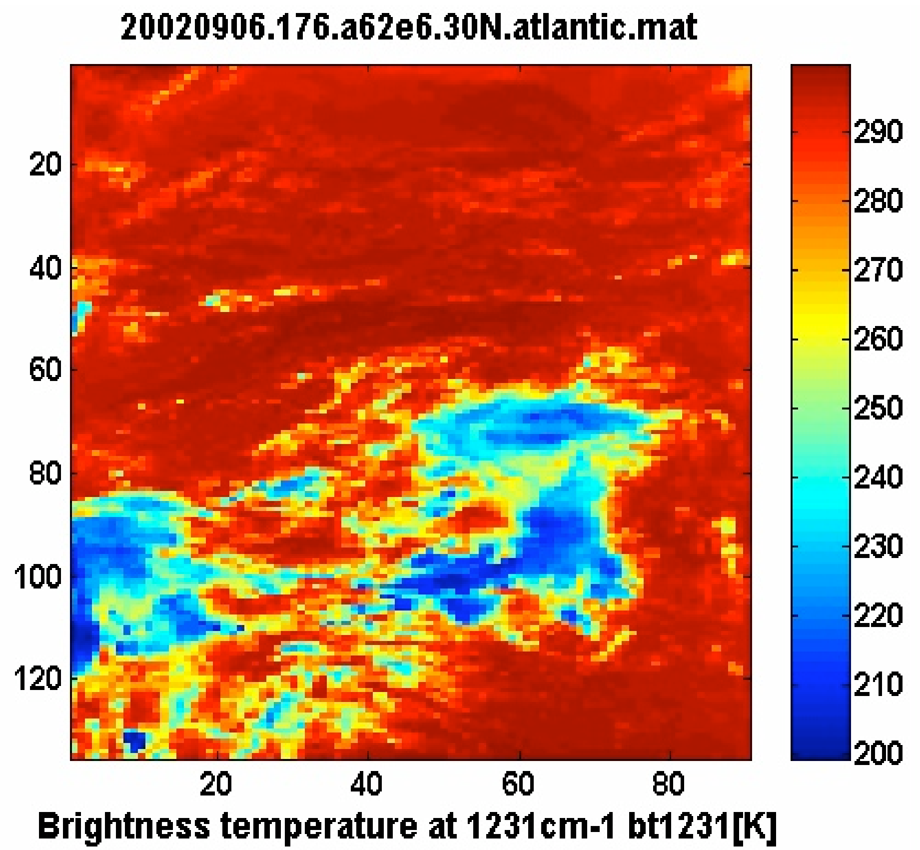
When a L1b or L2 flag is raised, the user can

- **skip the spectrum or retrieval**
- **evaluate if the flag is relevant to his application**
- **Ignore the flag at his own risk**

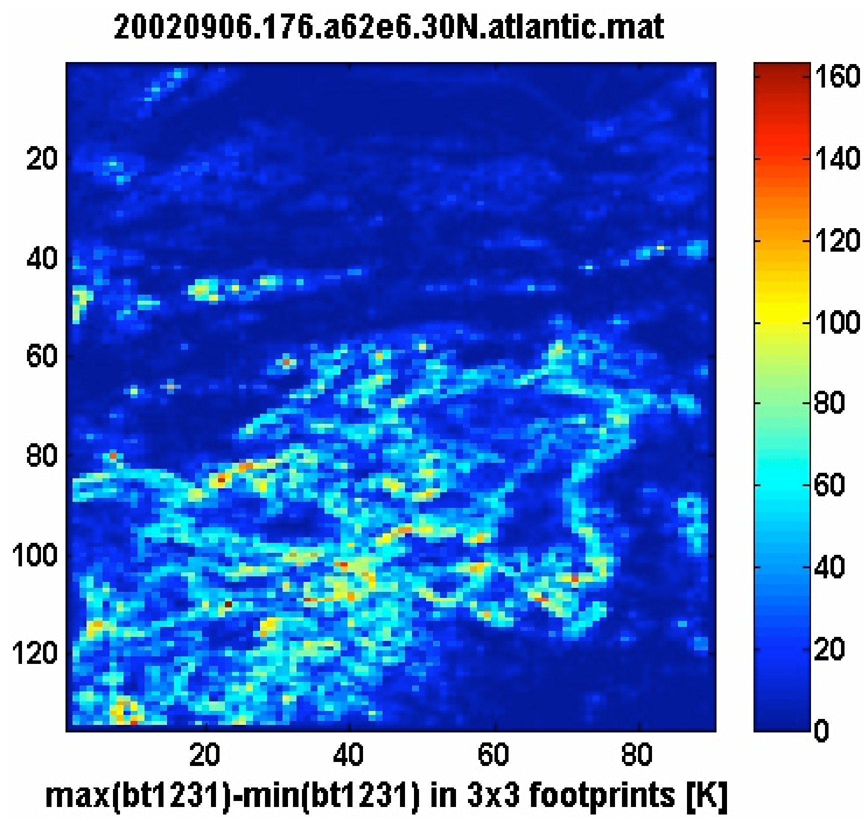
A considerable effort in the V4.0 delivery is in QA flag refinements
Three presentations this afternoon and tomorrow deal with QA.

Illustrations of effects using granule 176 from 20020906 centered in the Atlantic ocean centered on the Azores.

Temperatures range from 200K cloud tops to 300K at the surface



Gradients between adjacent footprints are as large as 80K



AIRS Calibration Accuracy, and Stability Validation

Radiometric accuracy and stability relative to RTG.SST

Spectral Stability relative to upwelling

L1 b Algorithm Theoretical Basis (ATBD) update required

AIRS IR Radiometry Extremely Stable

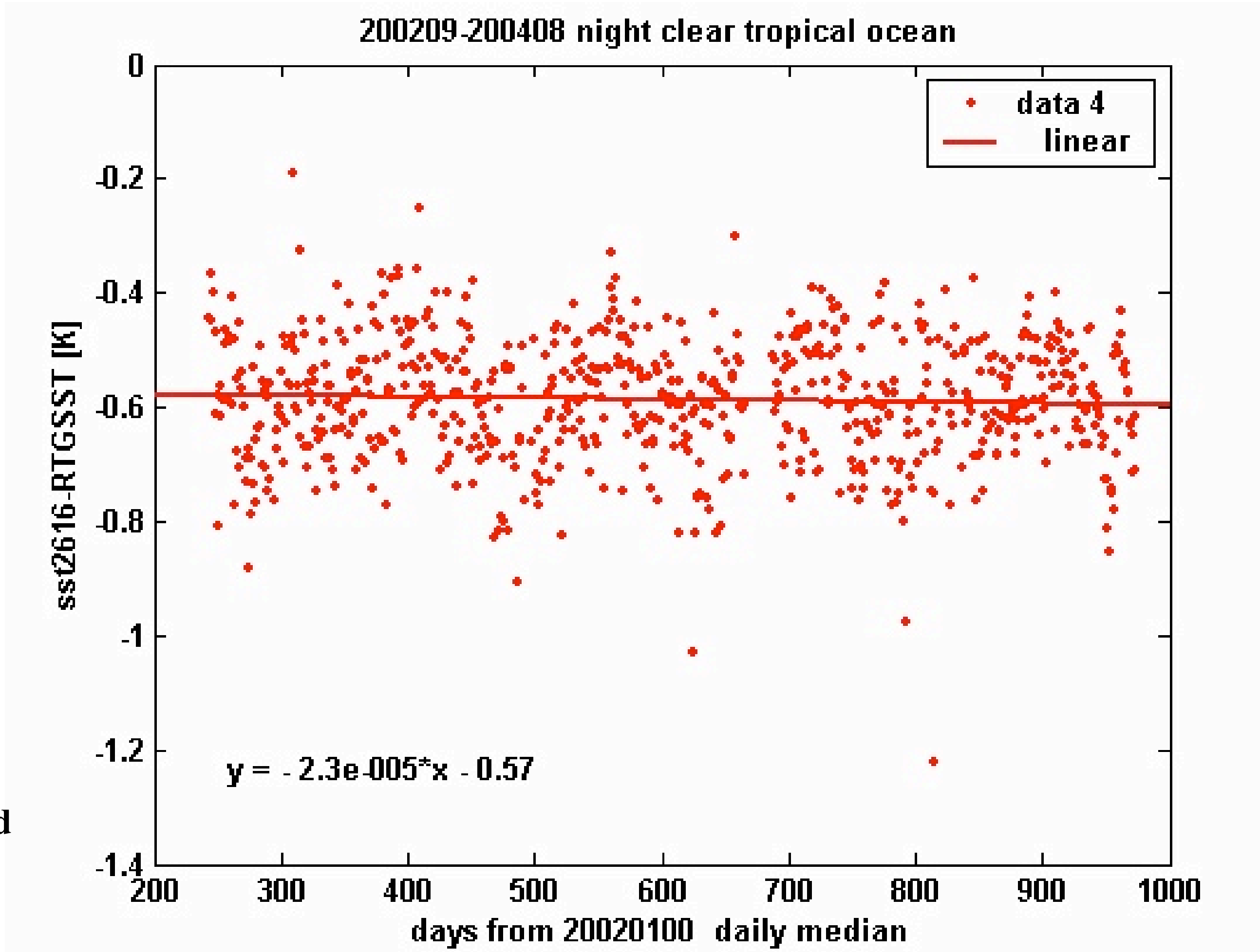
Instrument Stability Fundamental to Weather and Climate Quality Observations

SST2616 compared to RTG.SST at night
-0.57K bias observed
-0.37K bias expected

First principles using NIST traceable calibration

Stability better than 8 mK/Year

difference between observed and expected bias due to cloud contamination



Aumann et al 2004 "Evaluation of AIRS Data for Climate Applications"
SPIE 5570b Las Palmas September 2004

AIRS IR Absolute Radiometry better than 0.2K

SST1231 compared to RTG.SST

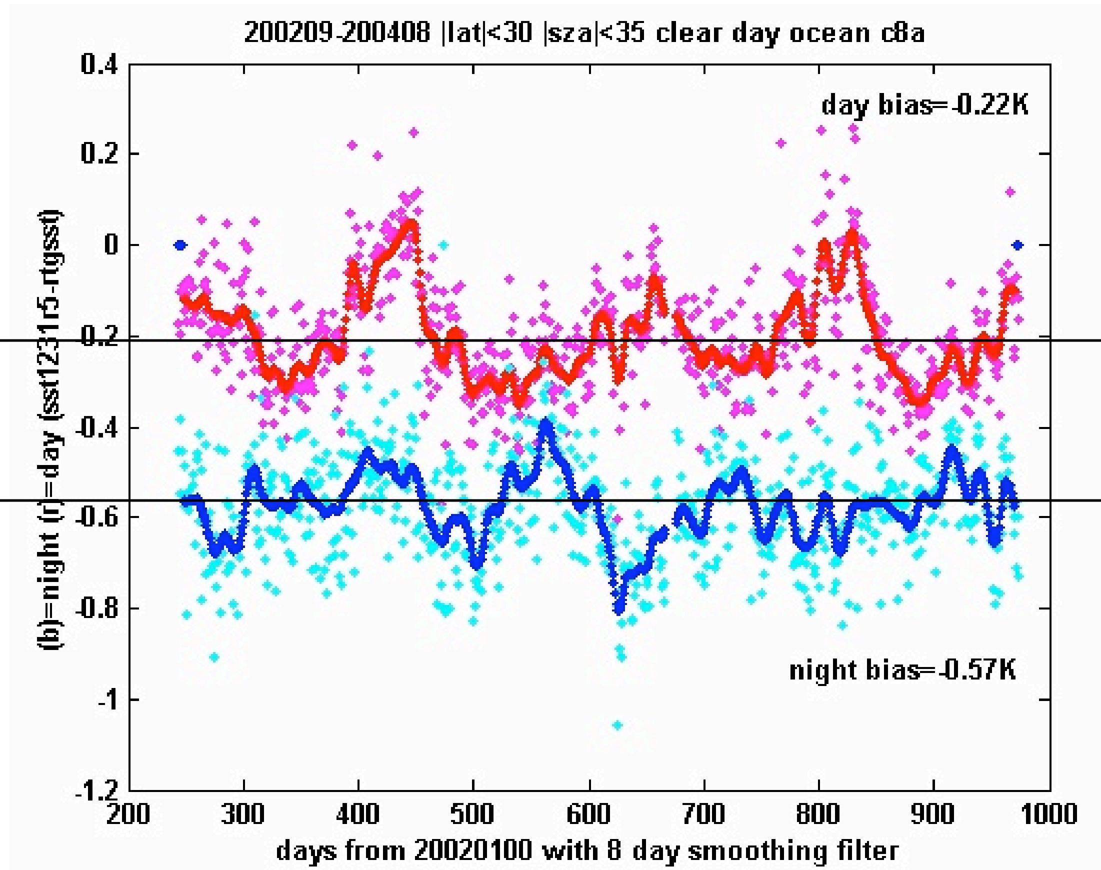
two year mean

day bias=-0.22K
night bias=-0.57K

day-night bias observed 0.35K
MODIS 0.37K

day bias observed –0.22K
expected zero

explanation: low cloud contamination



Aumann et al 2004 Denver August 2004 SPIE 5548-42

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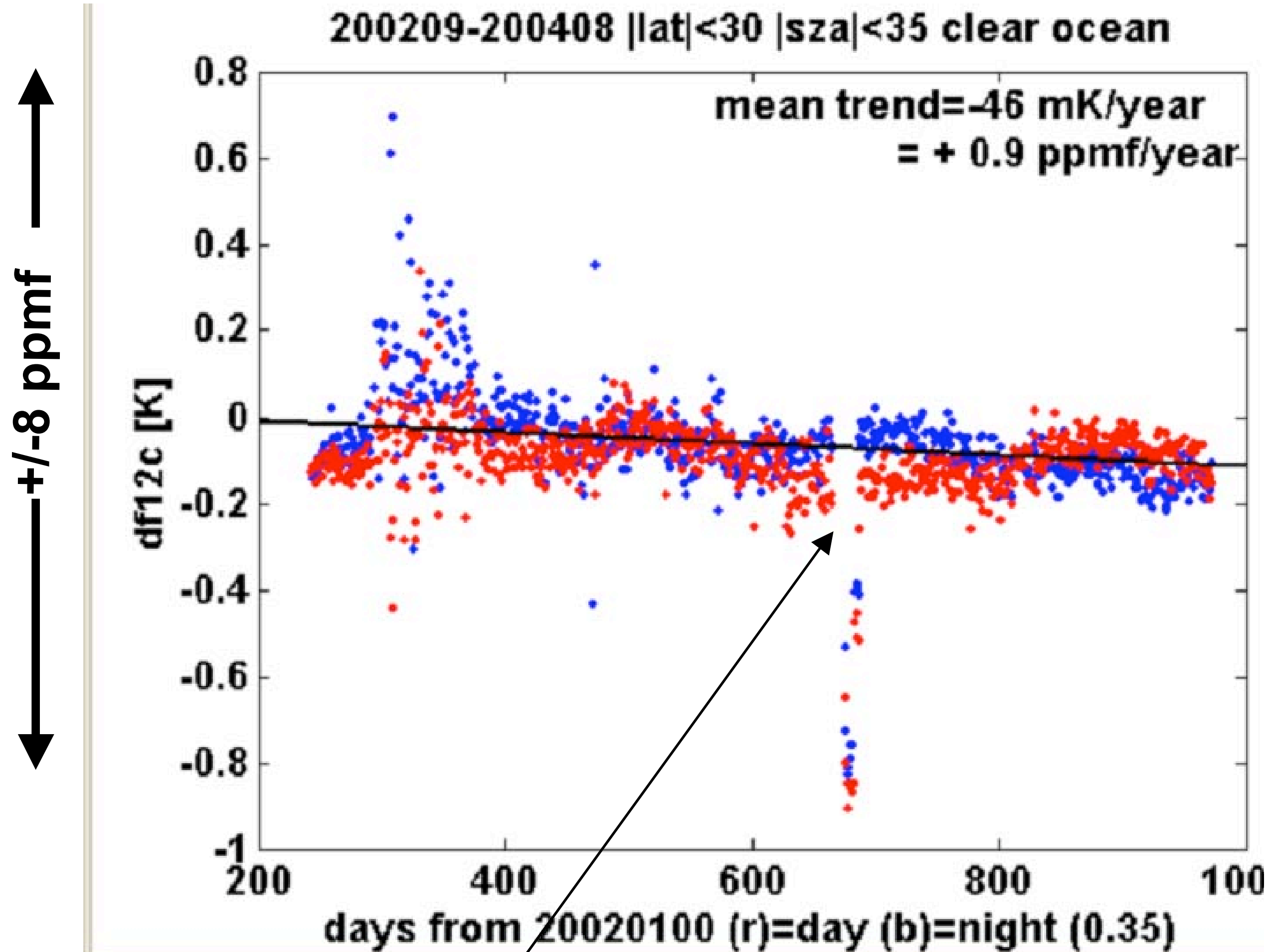
AIRS spectral calibration more accurate and stable than the +/-8 ppmf required for weather applications



November 2003 protective shut down due to Solar flair

SRF centroids determined relative to resolved upwelling spectral features

knowledge within 0.2 ppmf

stability +0.9+/- 0.5 ppmf/year

The trend needs to be corrected for critical climate applications

Day/night (red/blue) variability under investigation

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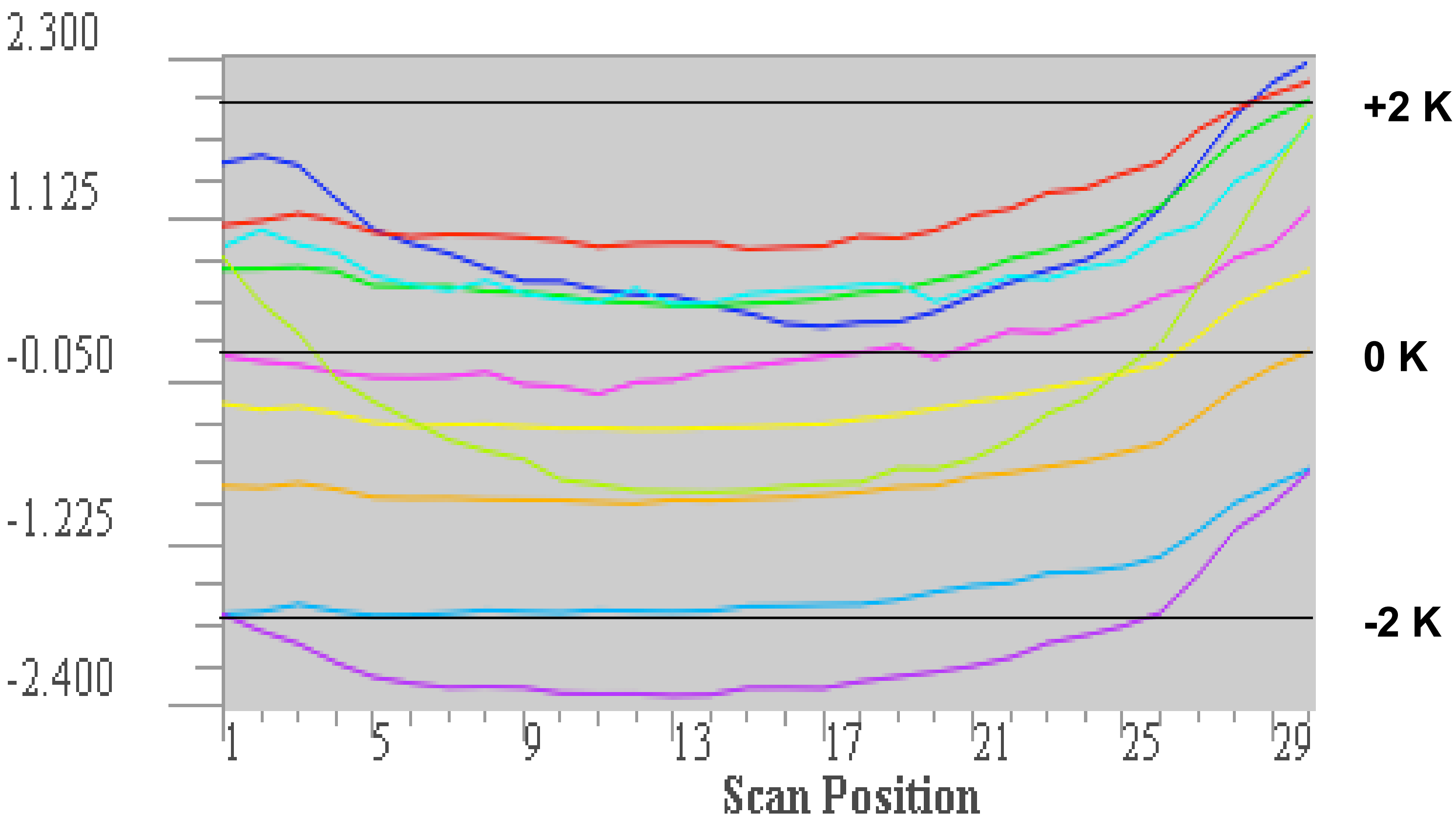
AMSU Level 1b

The AMSU is used for the initial estimate of the T(p) profile and the clear column radiance.

The AMSU calibration is complicated by sidelobe issues.

Mean bias over ocean for AMSU channels 5 through 14 using (btemp.antenna-calc.ECMWF)



The scan position dependent bias is a calibration artifact

McMillin /NESDIS

The radiances are statistically bias corrected in level 2 processing using empirical tuning.

The empirical bias correction appears to be stable

Closure is required on AMSU Level 1b

L1b product status has to upgraded to "beta validated".

RTA

The radiative transfer algorithm (RTA) converts the the signal from surfaces and layers in the atmosphere to the signal seen from space.

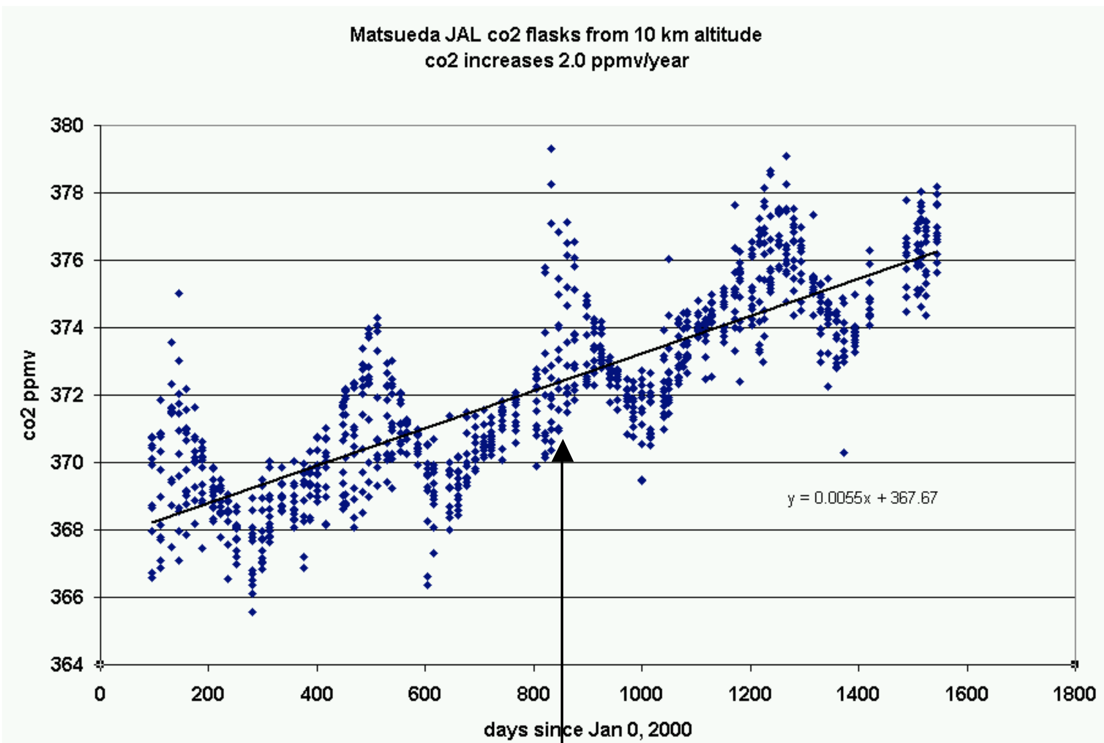
Evaluation of the (observed - calculated.ECMWF) indicates no scan angle dependence.

Residual frequency dependent bias at the less than 0.5K level may be due to systematic offsets in the ECMWF analysis.

Bias change as function of time at the 100mK/year level in co2 sensitive channels is due to increase in co2 column abundance of 2.2 ppmv/year

RTA

What may be good enough for weather forecasting or 1K/1km requirements is not good enough for climate quality work



EOS Aqua launch

At the level of AIRS sensitivity, the atmosphere is not as simple as the current RTA

Global change is already evident in the AIRS data after only two years.

The RTA still uses the at launch 370 ppmv co2

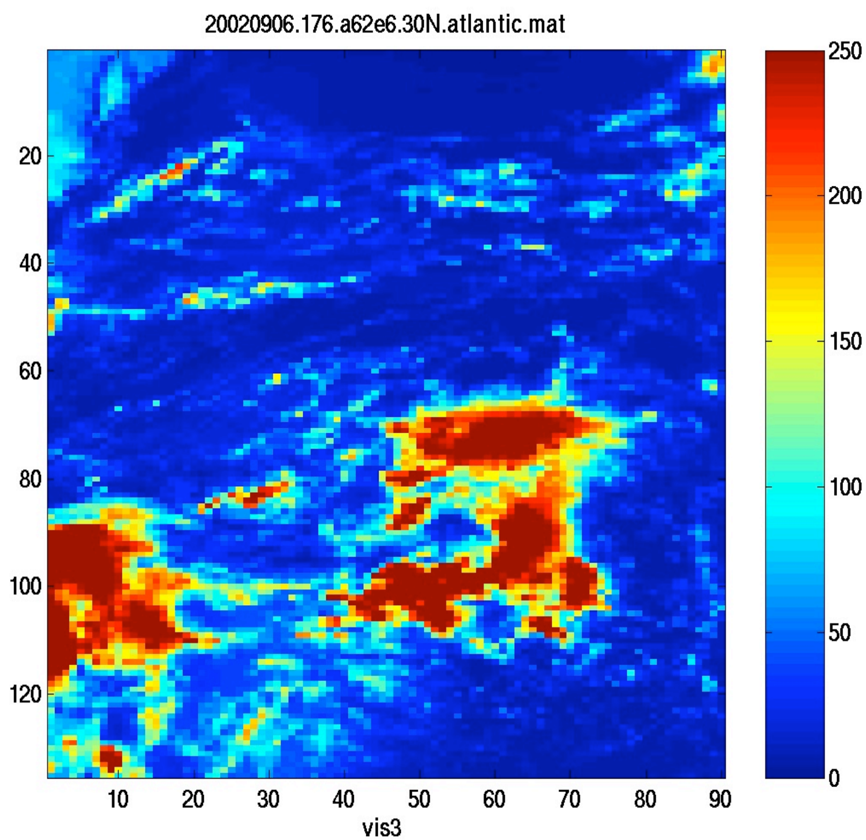
Level 2 Status

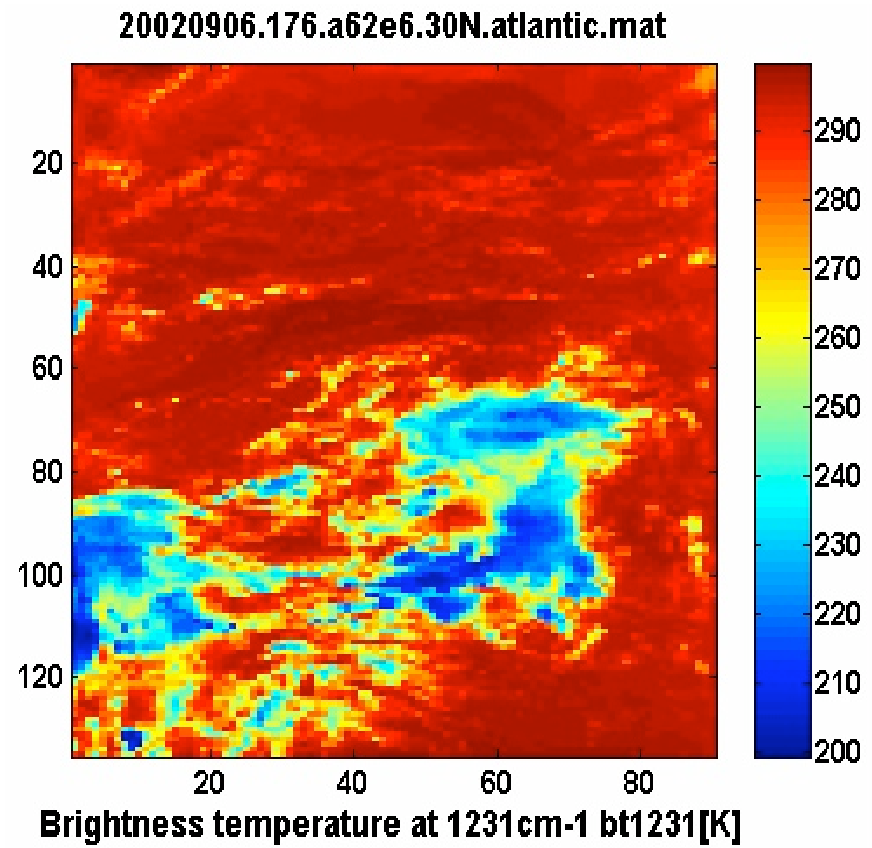
- Cloud-clearing
- T(p), q(p) retrievals
- Error estimation
- Validation

The Level 2 Algorithm Theoretical Basis Document needs to be updated

Level 2 (geophysical) Product Status with examples from 20020906.176

vis3



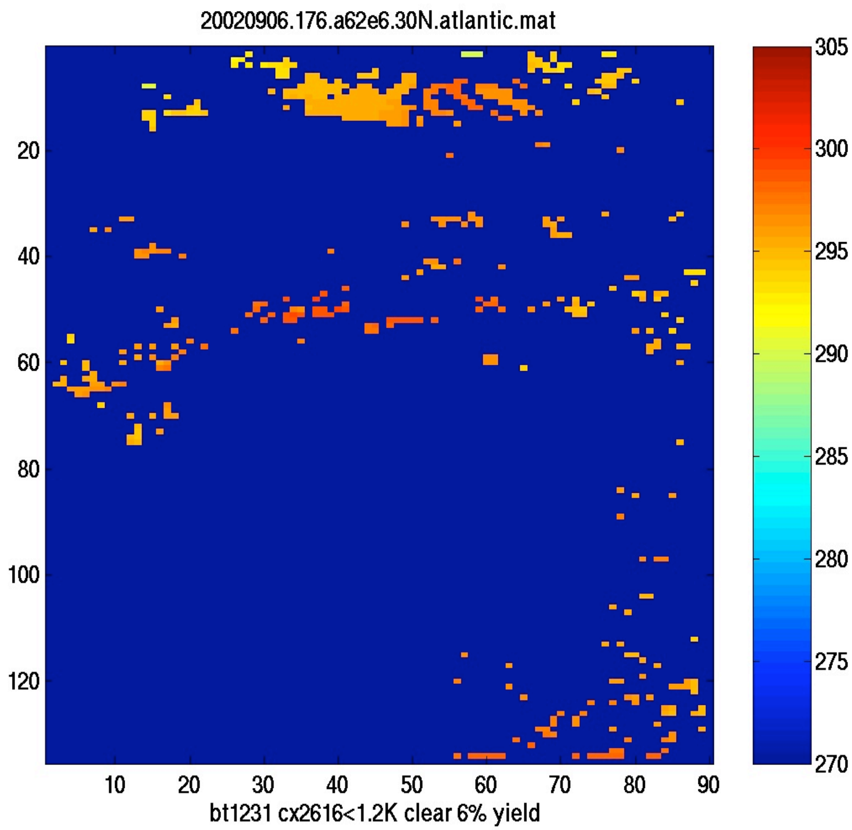


Obtaining good retrievals in the presence of clouds is a key requirement

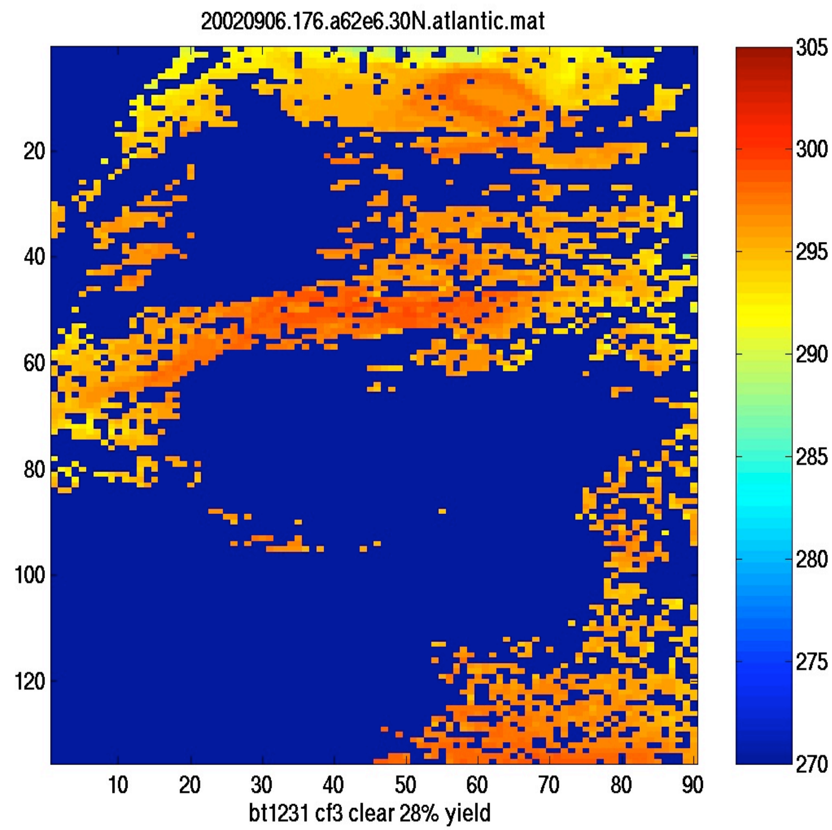
H. H. Aumann

Obtaining good retrievals in the presence of clouds is a key requirement for forecast impact

Only 6% of the spectra are cloud free using the classical spatial coherence test



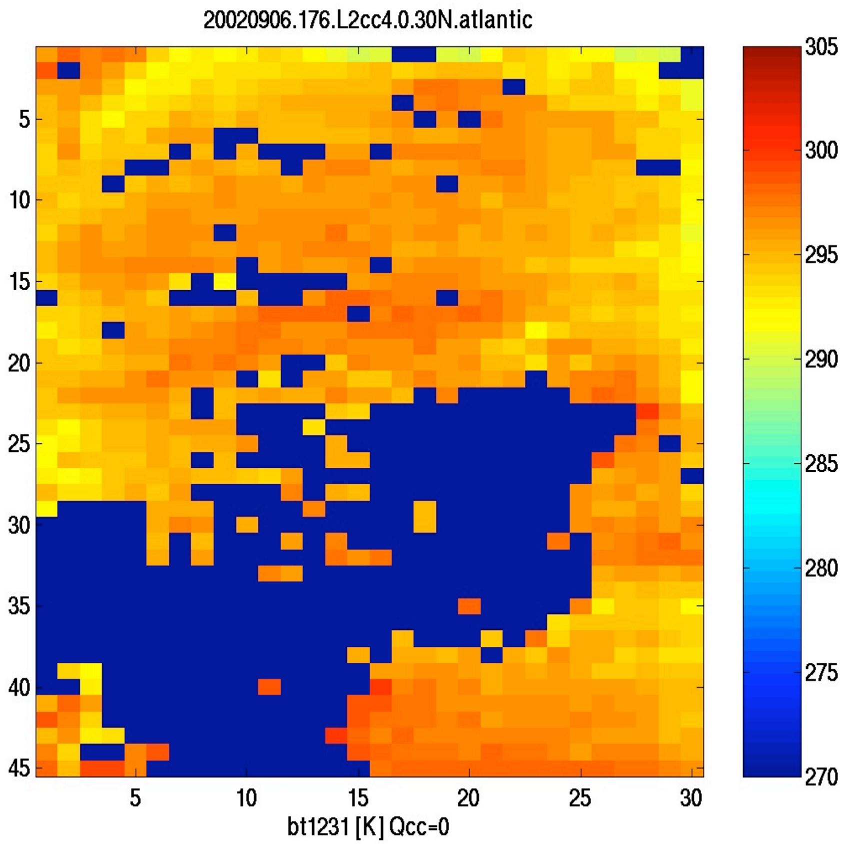
28% of the spectra are reasonable cloud free using the cf3 spectral filter



The cf3 spectral filter use 2388 cm-1 and 2387 cm-1 channel and high SNR at 250K.

Obtaining good retrievals in the presence of clouds is a key requirement for forecast impact

Only 68% of the spectra can be used after cloud-clearing



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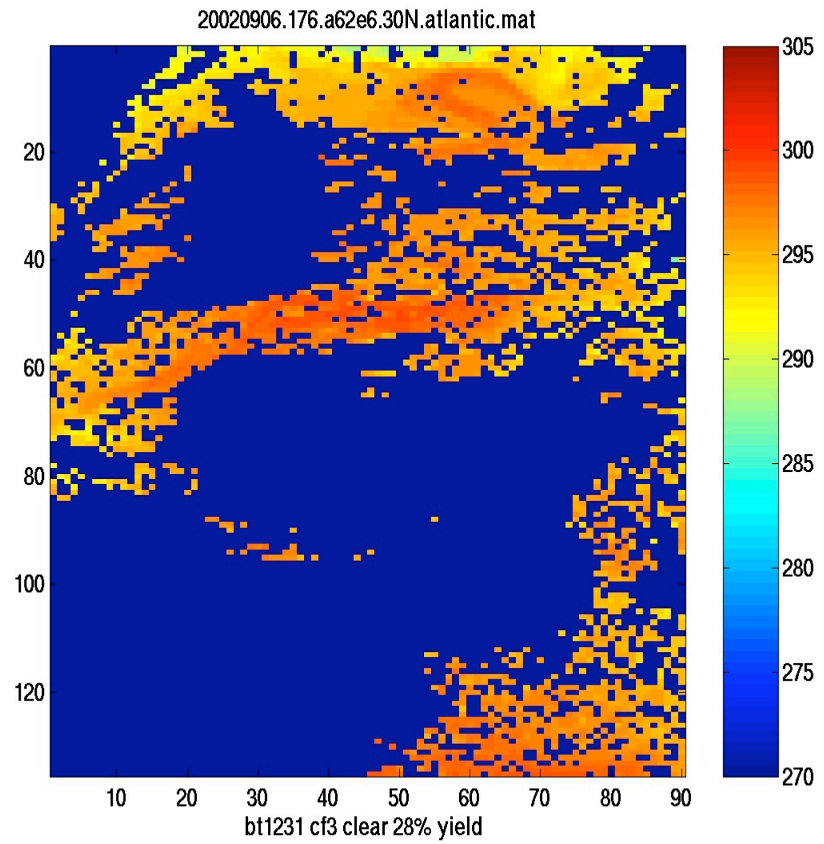

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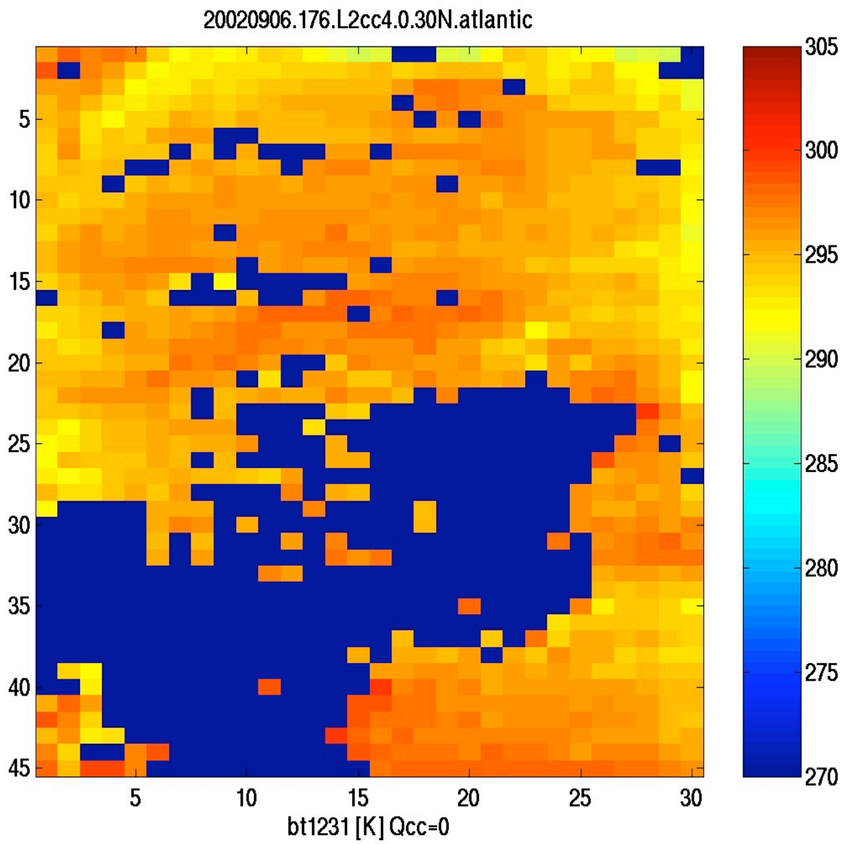
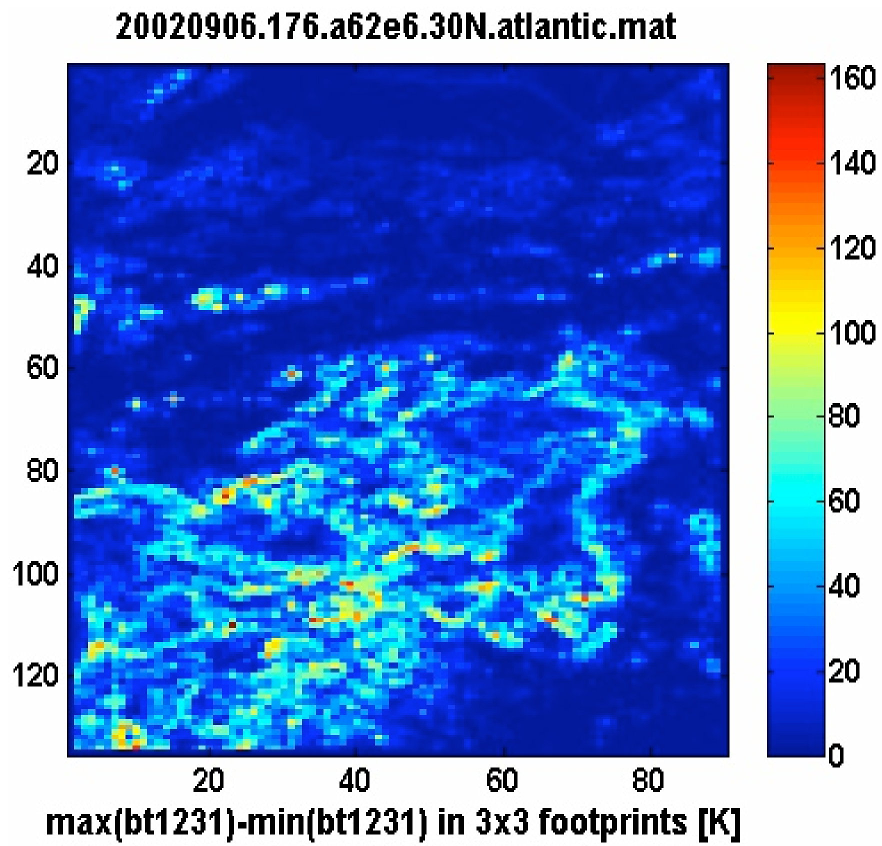


The cloud-clearing algorithm has difficulties in the areas of steep gradients



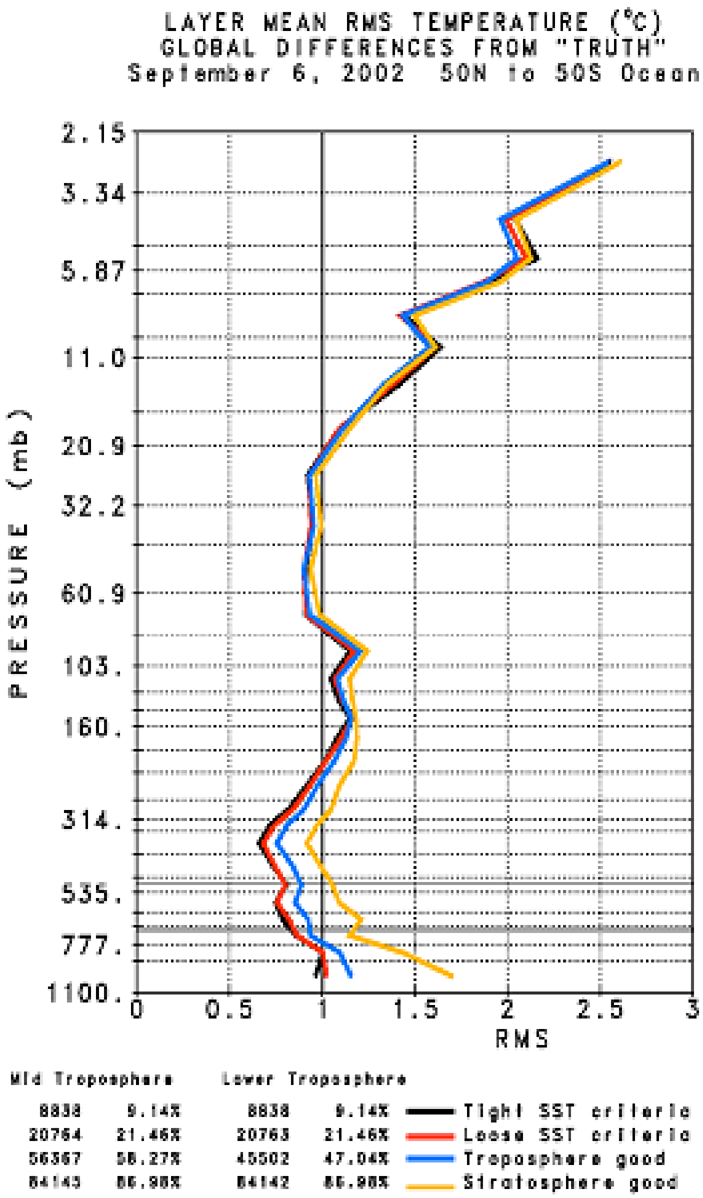
AIRS/AMSU/HSB

Level 2 Validation

Initially based on ECMWF comparisons

Now switching to more accurate ARM/CART atmospheric state definition during EOS Aqua overpasses

Analysis complicated by lack of error estimates in the level 2 products

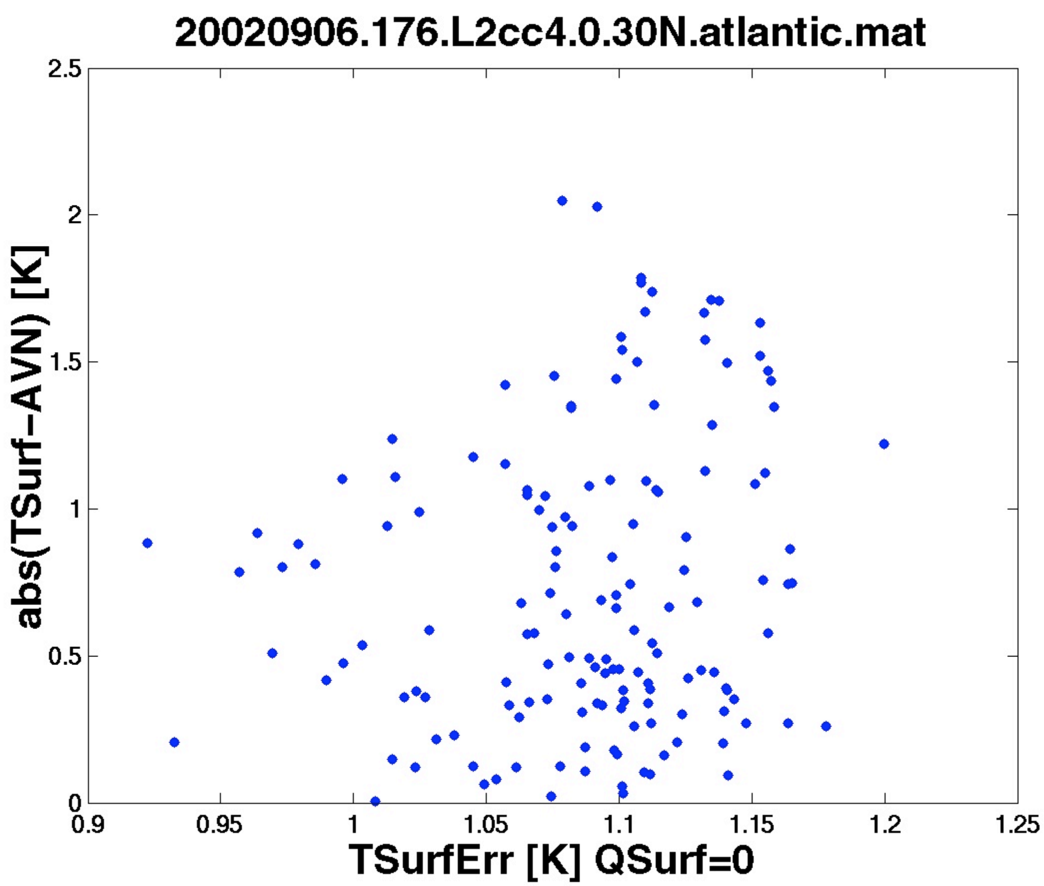


1 K rms in 1km layers in the troposphere achieved for non-polar ocean cases relative to ECMWF analysis

Susskind November 2004 Hawaii meeting on "Sounding of the Environment"

H. H. Aumann

Error Estimates for the retrieval from each footprint are key to data assimilation and level 2 product generation



There is little correlation between the estimated error for each retrieval and the demonstrable error based on surface truth

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AIRS Data Assimilation

AIRS radiances have been assimilated into the operational forecast at ECMWF and UKMeto since May 2004.

Experimental radiance and L2 assimilation at NCEP/DAO

All NWC report significant positive forecast impact with AIRS data

Atmospheric InfraRed Sounder (AIRS) Observations: Impact on Weather Forecasts

J. Le Marshall, J. Jung, J. Derber, R. Treadon, S.J. Lord,
M. Goldberg, W. Wolf, H.C. Liu, J. Joiner, J. Woollen and R. Todling.
NOAA/NASA/NAVY/Air Force Joint Center for Satellite Data Assimilation
Camp Springs, MD

"The improvement in forecast skill at 6 days ....equivalent to gaining an extension of forecast capability of several hours in both hemispheres"

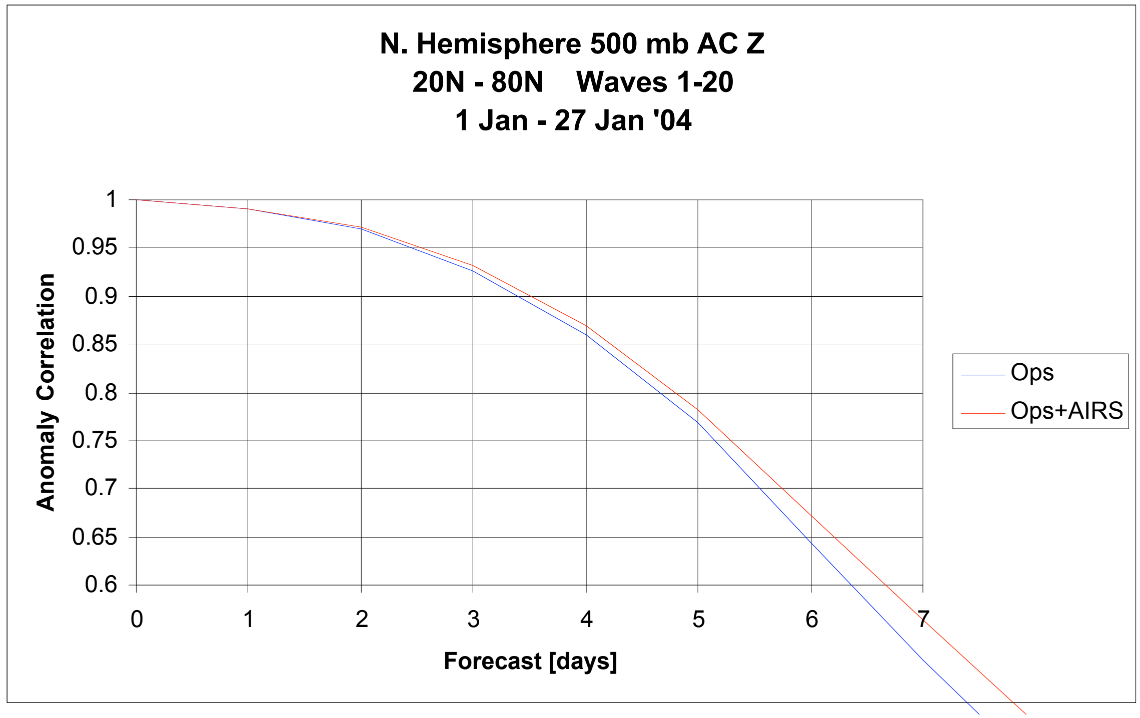
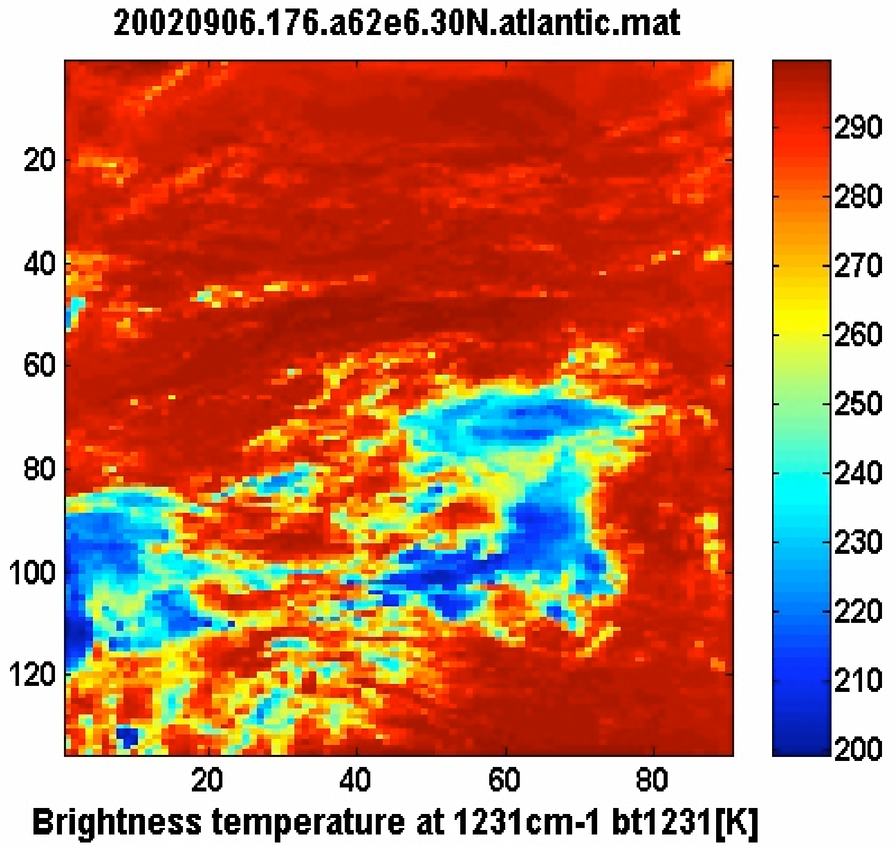


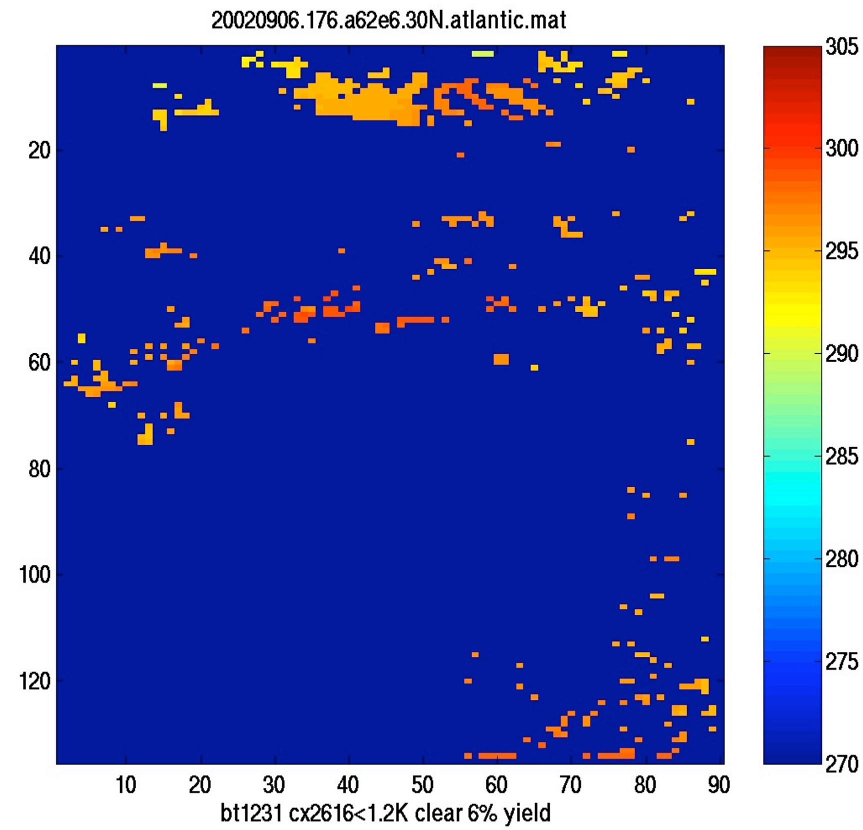
Figure 2. 500hPa Z Anomaly Correlations with (Ops.+AIRS) and without (Ops.) AIRS data, Northern hemisphere, January 2004

0.5% AIRS data utilization limits forecast impact

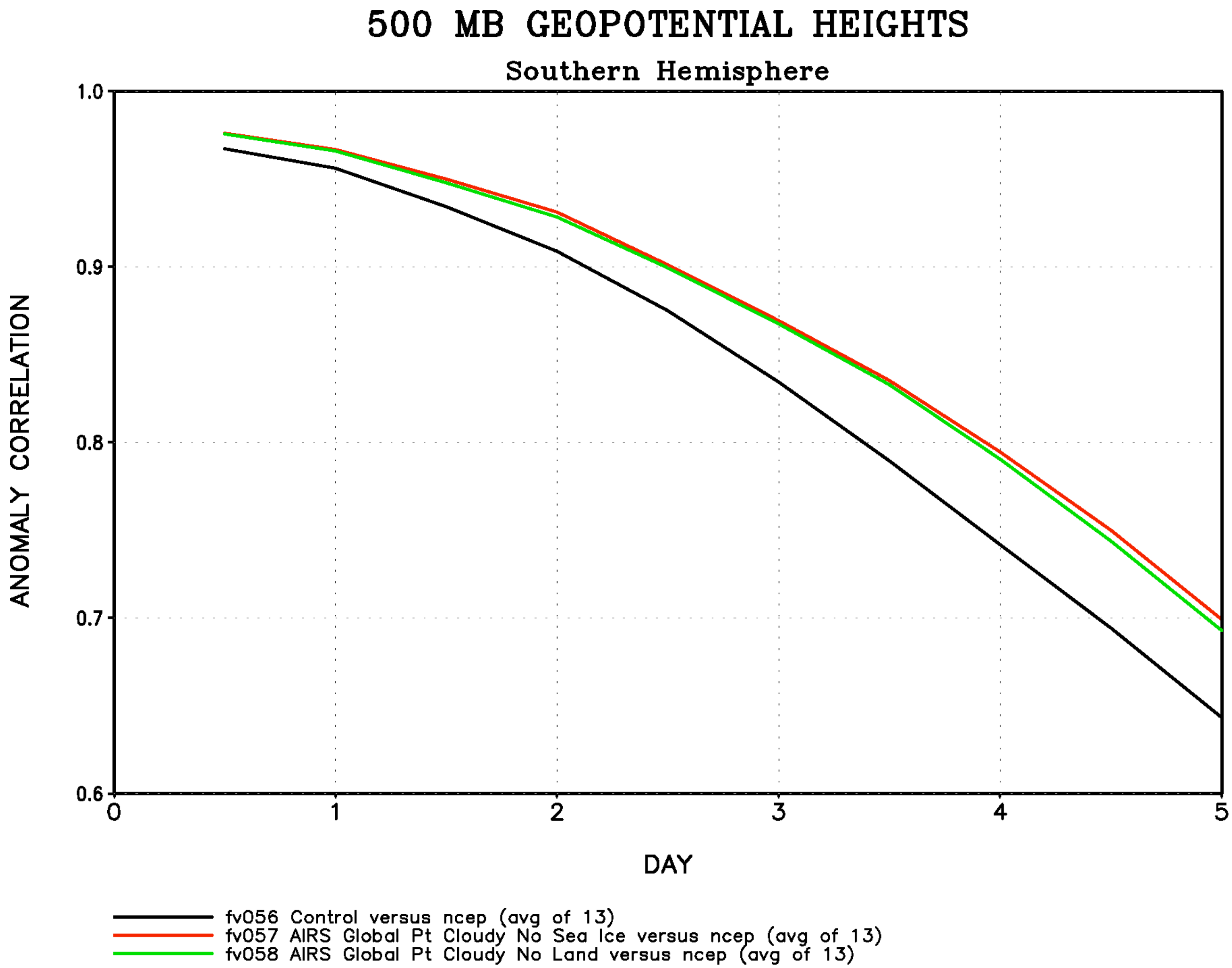
Table 2: AIRS Data Usage per Forecast Initialization

Data Category	Number of AIRS Channels
Total Data Input to Analysis	~200×10^6 channels
Data Selected for Possible Use	~2.1×10^6 channels
Data Used in 3D VAR Analysis (Clear Radiances)	~0.85×10^6 channels





Bob Atlas (GSFC) assimilations of AIRS level 2 data shows improved 500 mb geopotential height anomaly correlation



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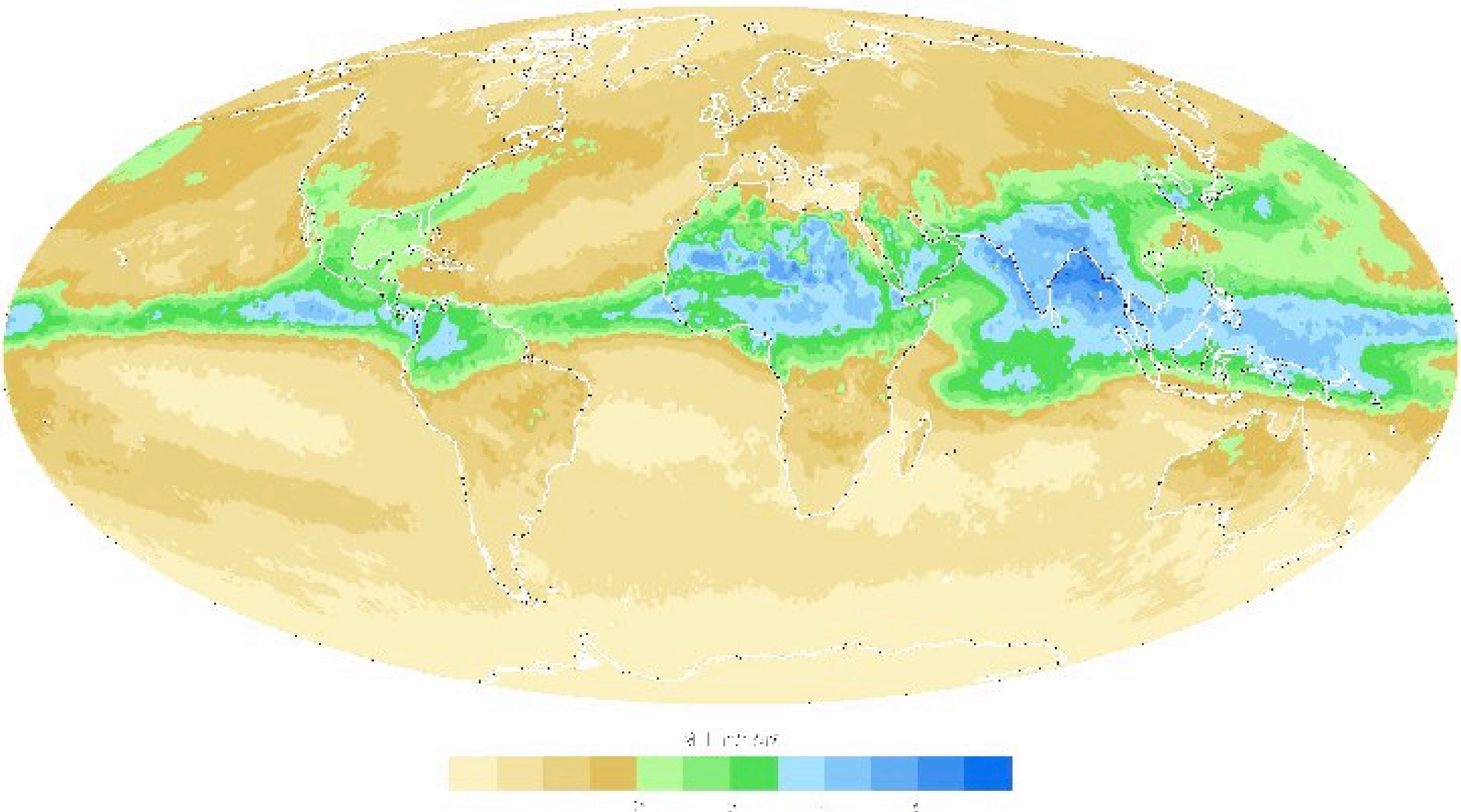
Level 3 Products

Level 2 products are mapped into daily, weekly and monthly level 3 products

This reduces the data volume by two orders of magnitude for climate research

The Level 3 products are currently only beta validated (not for research) partly due to the lack of error estimates for each retrieval

AIRS Upper Atmospheric Water Vapor (July 2003) level 3 product



10% of the water is above 600 mb
Upper tropospheric water transports moisture and latent heat away from the tropical oceans towards the poles.

H. H. Aumann
C. Thompson, E. Olsen

Standard Data Product Processing Status

Getting ready for V4.0 reprocessing

Level 1b

Level 2

> **T(p) q(p) validated over non-polar oceans**
> **with up to 80% clouds.**
> **Meets "radio sonde quality" 1K/1km requirement**

Level 3 products (beta validated)

Clear ocean/land data subset

AIRS Research Products

Only 320 of the 2378 AIRS channels are used for the T(p), q(p) retrievals and data assimilation

The remaining channels can be used for research products

The 320 channels were picked by the AIRS team with
an understanding of the instrument properties the calibration
and the details of the retrieval algorithm.

Developers of research product need to be very familiar with the channel properties file and QA flags

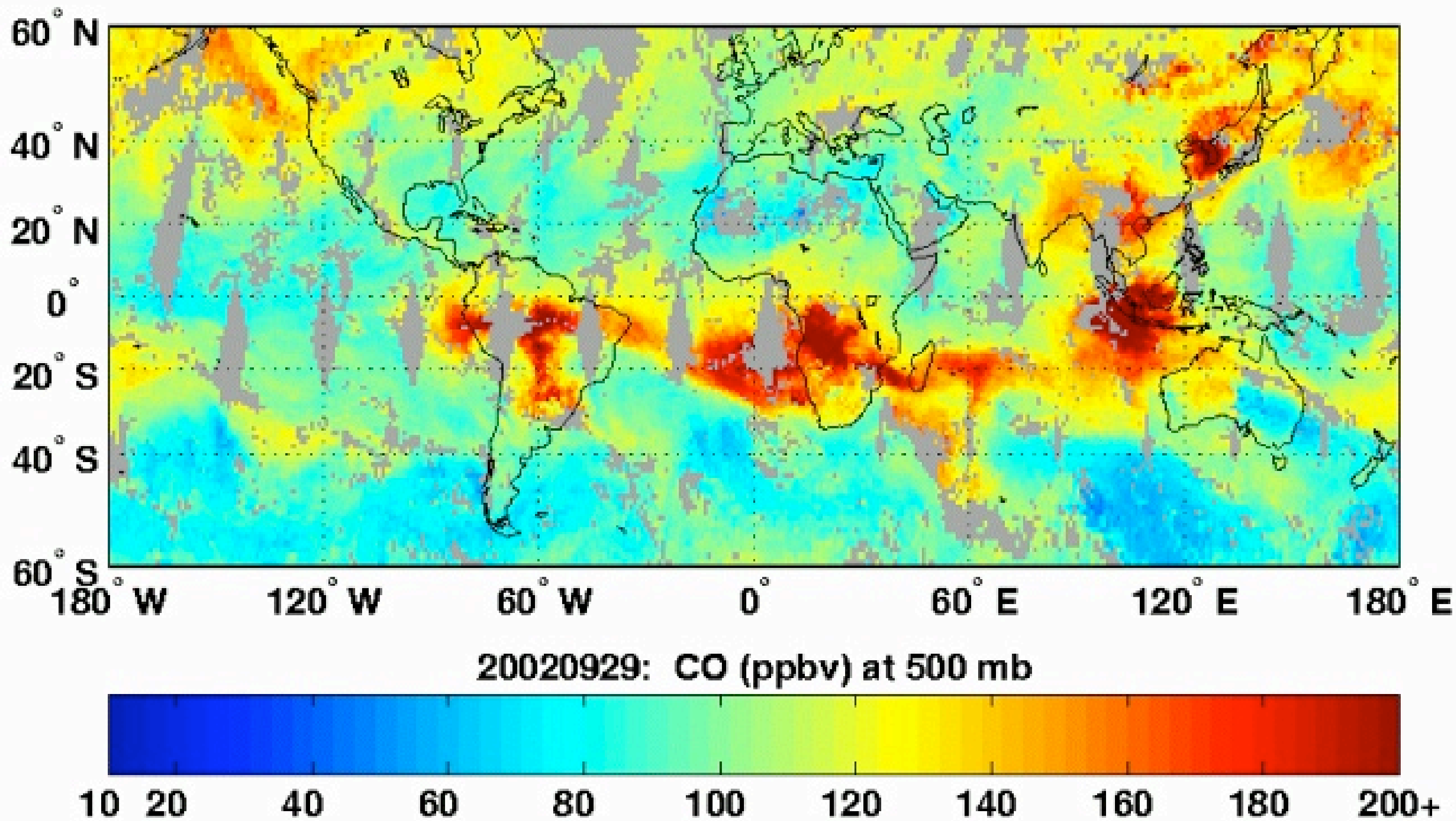
Research Products using AIRS data

McMillan: CO
Strow: SO2 and Aerosol
Fetzer et al.: Correlations between Kelvin Waves, OLR and UTW
Knutson Surface Emissivity
Aumann: Two year AIRS trends

Irion: Ozone
Li, Hunag, Revercomb Cloud Emissivity

+ Carbon Dioxide, Methane, OLR, and more

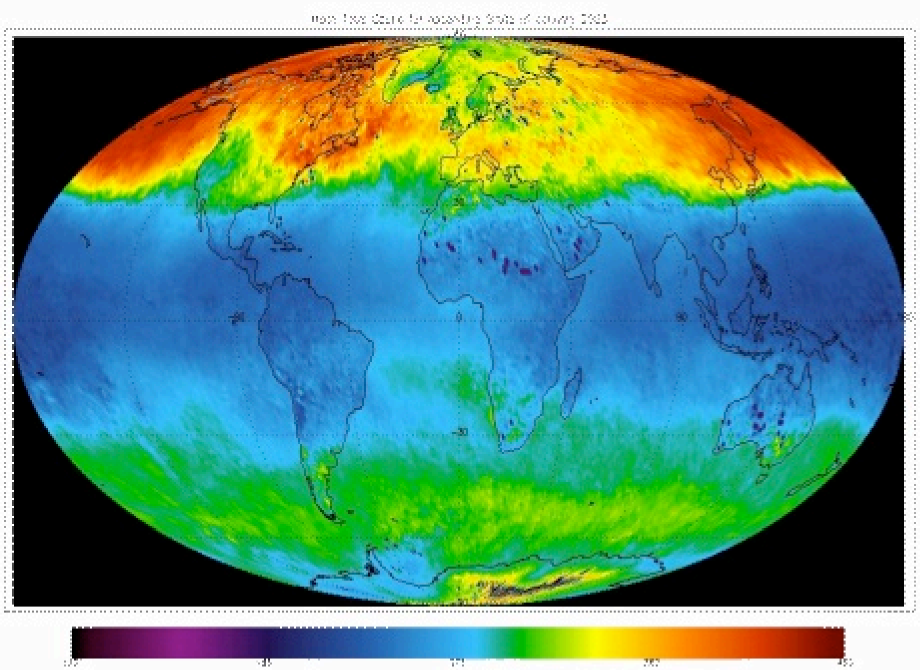
CO retrieved from 4.67 μm CO fundamental vibration-rotation band (2180-2220 cm^{-1})



Wallace McMillan et al. (2204)CO retrieval from AIRS. Submitted to GRL

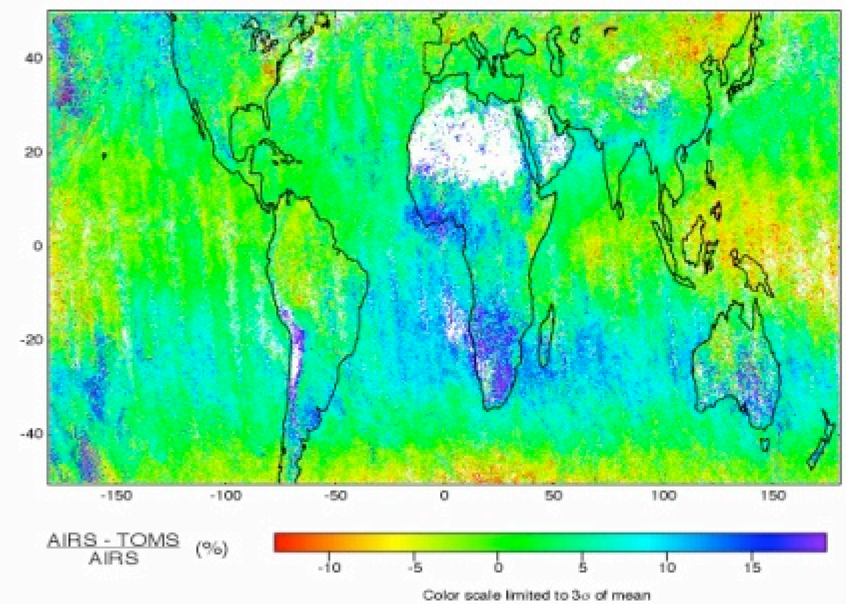
Irion: Day/night retrievals of Ozone with AIRS.

AIRS Monthly Ozone Product



AIRS Ozone Compared to TOMS

Avg = 3.1 ± 5.4 %



(W. Irion/JPL)

What's New from AIRS:

- Coverage of Ozone Hole in Polar Winter (Night);
- Tropospheric Ozone (In Progress)

AIRS Observations of Volcanic Eruptions

L. Strow, S. Carn, S. De-Souza Machado, Y. Edmonds (UMBC)

Under final review: Geophysical Res. Letters

Images below are differences in B(T) biases between two AIRS channels. (Biases are relative to ECMWF.)

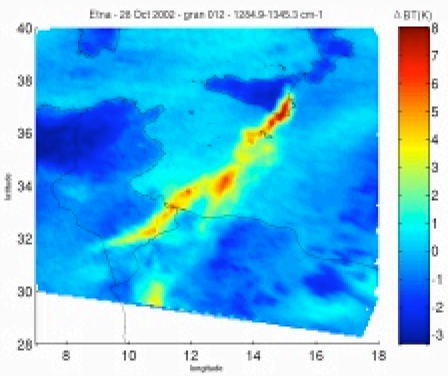
SO_2 Cloud: 1285 - 1345 cm^{-1} Bias

Ash Cloud: 1228 - 913 cm^{-1} Bias

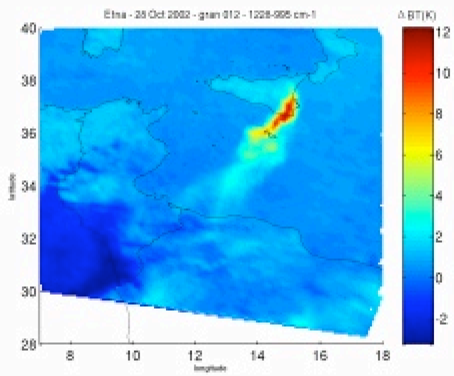
SO_2 and silicate spectral features are widely separated in AIRS IR spectra. Silicate features have opposite slope to cirrus in the 10-12 micron window.

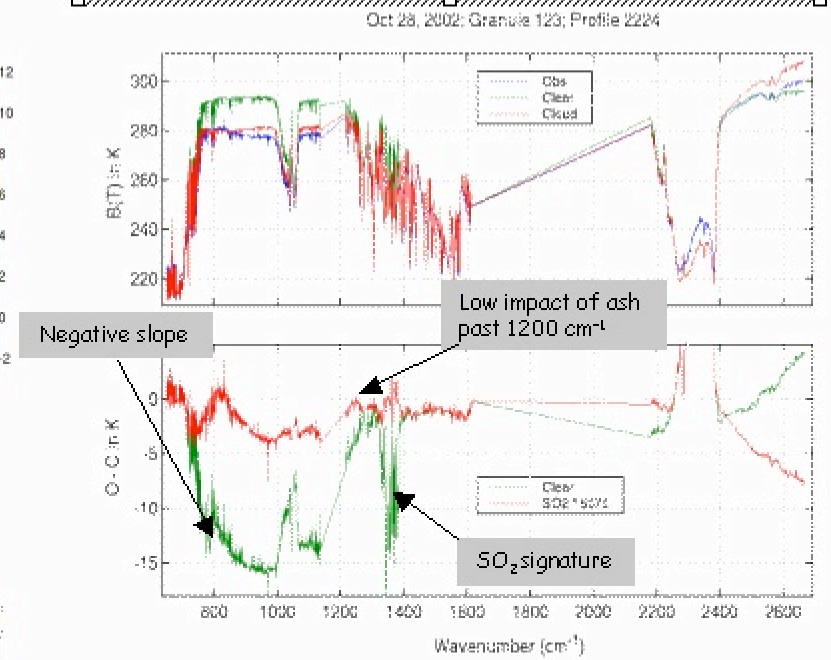
Mt. Etna Eruption (28 Oct 2002)

SO_2 Cloud



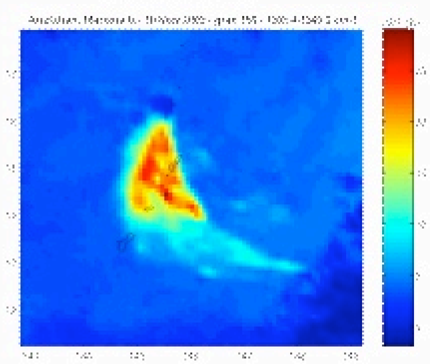
Ash Cloud



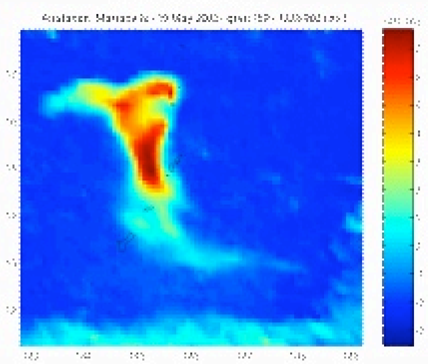


Anatahan Eruption (10 May 2003): Differential Movement of Ash and SO_2 Cloud

SO_2 Cloud



Ash Cloud



We have estimated total column amounts of SO_2 and ash emitted by Mt. Etna with reasonable agreement with other (error prone) estimates.

See: http://toms.umbc.edu/airs_archive.html for AIRS observations of other volcanic eruptions.

Observations of Dust with AIRS

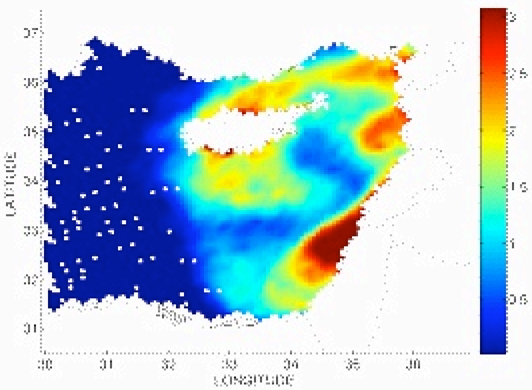
Case Study: *Mediterranean Storm in October 2002*

L. Strow, S. De Sousz-Machado, UMBC

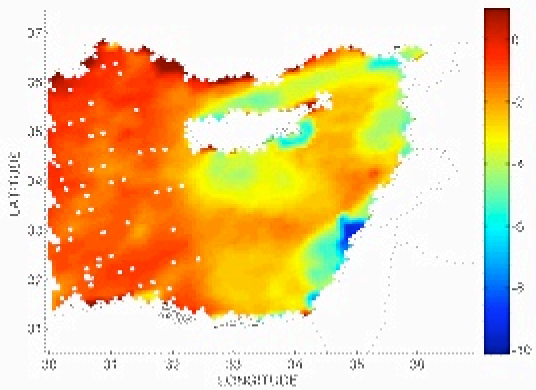
Manuscript in preparation

AIRS can measure dust at night!

B(T) OBS 1231 - 991 cm^{-1} Sensitive Dust Detector

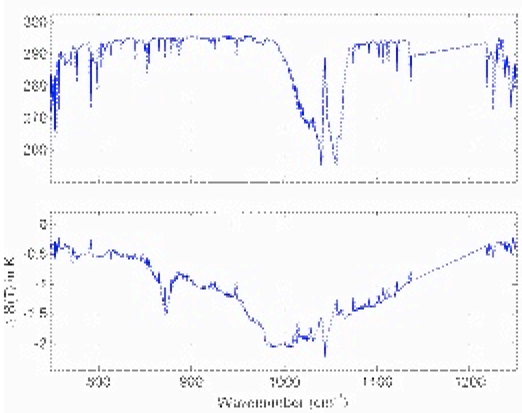


991 cm^{-1} Bias relative to ECMWF shows up to 10K BT depression

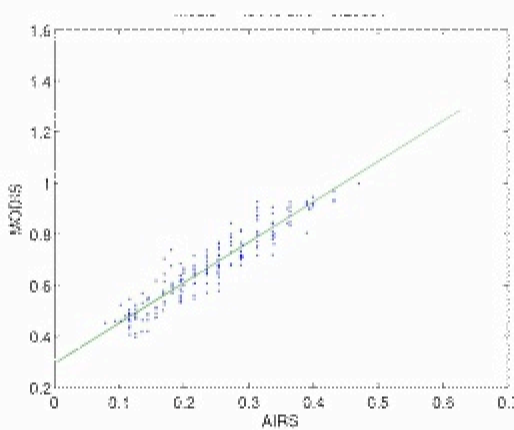


MODIS visible image shows similar storm morphology

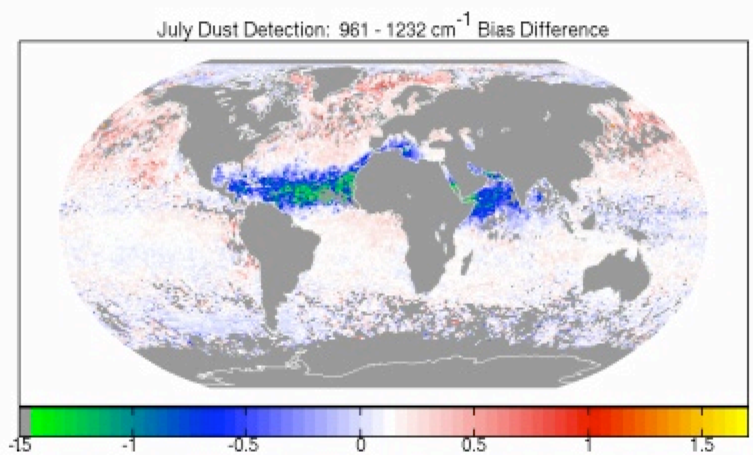
Top: *Average B(T) spectrum*
Bottom: *Average dust signature*



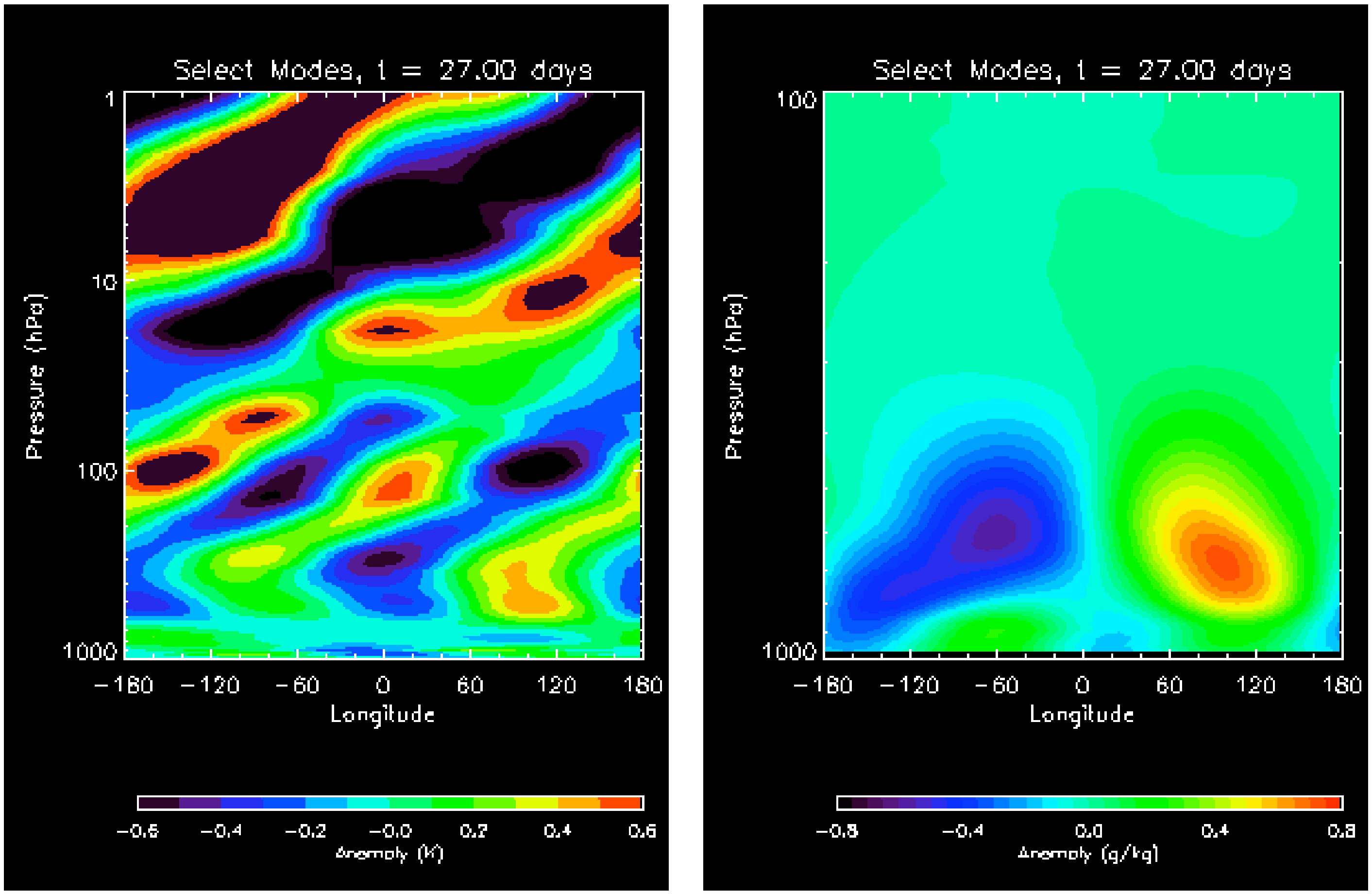
MODIS vs AIRS observed optical depths (for AIRS 900 cm^{-1} channel)



Dust seen globally with AIRS: *Average dust signal for July 2003*

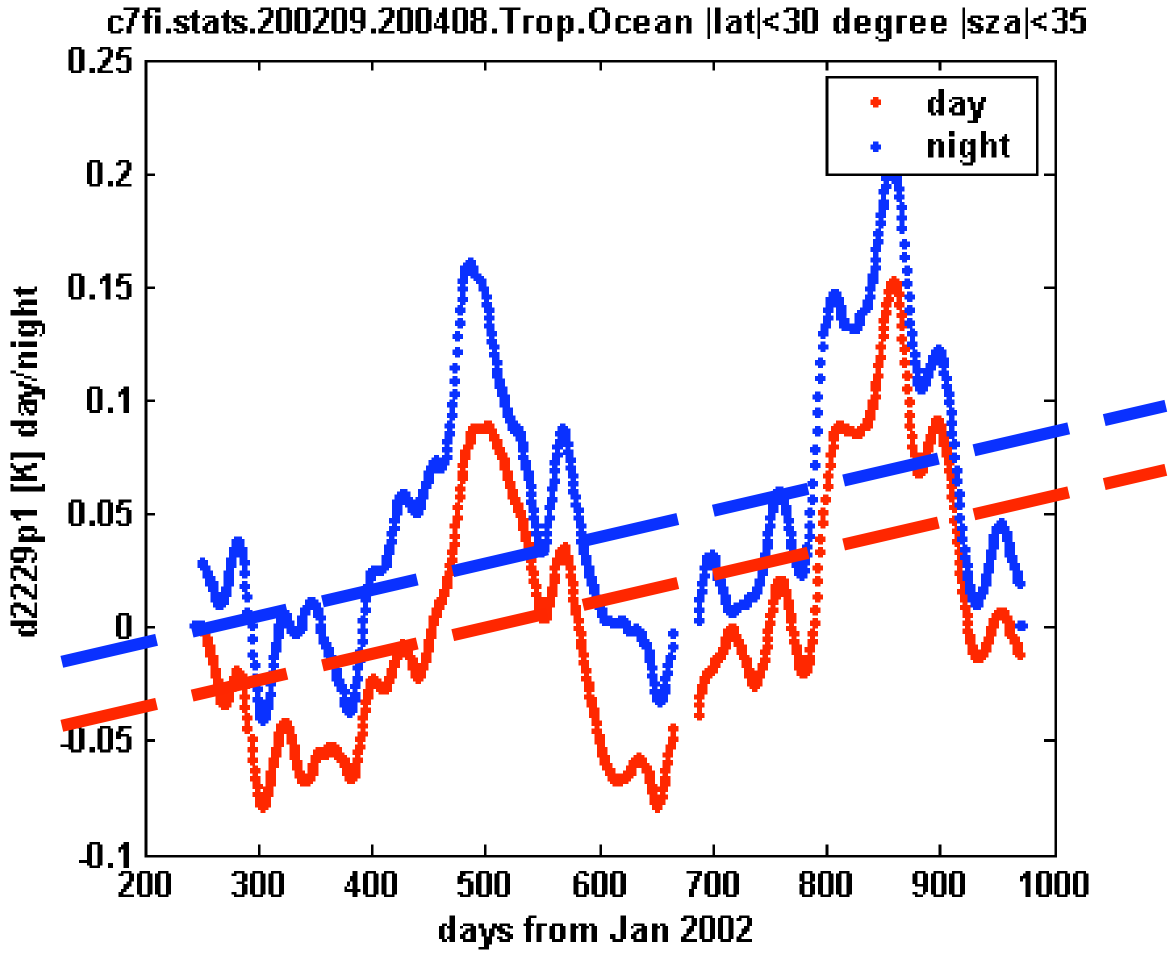


S. S. Leroy, E. J. Fetzer and S. L. Granger (2004) "The interaction of Atmospheric Kelvin Waves with Humidity and Convection as Observed in AIRS Data. Submitted to Journal of Geophysical Research.



H. H. Aumann

The 47+/-9 mK/year trend in the difference between bt2229.- bt2388 is explained by a 2.2 ppmv/year co2 and 0.6 ppmb/year n2o increase



Aumann et al 2004 (Submitted to GRL)

H. H. Aumann

AIRS Product Upgrade Plans

Updated ATBD for level 1b and Level 2

Validation of level 2 products over land and polar

Global emissivity maps to facilitate data assimilation over land

Cloud-clearing for single footprints for better horizontal resolution

Global co2 and ch4 maps

Measure five year trend in mid tropospheric temperatures and water

Use AIRS data for intermediate range (El Nino) forecasting

Improve AIRS data utilization by science community

Summary

With more than two years of data the stability and accuracy of the AIRS calibration is established at a climate quality level and sets the standard for future hyper-spectral sounders

AIRS data are used operationally in the forecast with positive impact

Level 2 products have validated 1K/1km accuracy over non-polar ocean with about 50% yield from the bottom to the top of the atmosphere

Publications of research products are emerging

The first climate trends are showing up in the AIRS data